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1 **LOCATION PATTERNS AND METHODS AND APPARATUS FOR**  
2 **GENERATING SUCH PATTERNS**

3

4 **CROSS REFERENCE TO RELATED APPLICATIONS**

5 This application is related to the following Patent Applications: US Patent  
6 Application Serial No.\_\_\_\_\_ filed September 10, 2003, entitled  
7 "Printing Digital Documents" (HP reference 200207150-1; Attorney docket  
8 621239-6); US Patent Application Serial No.\_\_\_\_\_ filed  
9 September 10, 2003, entitled "Methods and Apparatus for Generating  
10 Images" (HP reference 200207059-1; Attorney docket 621240-1); US  
11 Patent Application Serial No.\_\_\_\_\_ filed September 10, 2003,  
12 entitled "Location Patterns And Methods And Apparatus For Generating  
13 Such Patterns" (HP reference 200310543-1; Attorney docket 621242-7);  
14 British Patent Application No.\_\_\_\_\_ filed September 10, 2003,  
15 entitled "Methods, apparatus and software for printing location  
16 pattern" (HP reference 200300566-1; Attorney docket JL3824), the  
17 disclosure of which is hereby incorporated herein by reference; and, British  
18 Patent Application No.\_\_\_\_\_ filed September 10, 2003, entitled  
19 "Printing of documents with position identification pattern" (HP  
20 reference 200310132-1; Attorney docket ASW1329), the disclosure of  
21 which is hereby incorporated herein by reference.

22

23 **FIELD OF THE INVENTION**

24 This invention relates to location patterns, typically printed on a  
25 document and typically used to allow the position of a device such as  
26 a pen to be determined relative to the pattern, and to methods and  
27 apparatus for generating such patterns.

28

29 **BACKGROUND TO THE INVENTION**

30 The invention arose out of a consideration of the work of Anoto™  
31 Group AB and others in relation to digital pattern paper and digital

1 pens. It is convenient to discuss the invention in that contextual  
2 background, but it will be appreciated that the invention is not  
3 restricted to use with any proprietary system.

4

5 The prior art Anoto digital pen and paper system is described on their  
6 website [www.anotofunctionality.com](http://www.anotofunctionality.com). However, since the content of  
7 websites can change with time it is to be made clear that the prior art  
8 admitted is that which was published on their website no later than  
9 the day before the priority date of this patent application. It is also  
10 appropriate to include in this application itself a brief review of the  
11 Anoto system.

12

13 Figure 1a shows schematically part of an A4 sheet 10 of Anoto digital  
14 paper. The sheet 10 has printed on it a part of a very large non-  
15 repeating pattern 12 of dots 14. The dots 14 of the pattern 12 are  
16 printed using infra-red absorbing black ink. The dots give the sheet  
17 12 a pale grey appearance. An enlarged view of a small area of the  
18 pattern 12 is illustrated in Figure 1b.

19

20 As is shown in the Figure 1b, the position identifying pattern 12 is  
21 made up of a number of dots 14 arranged on an imaginary square  
22 grid 16. The grid 16 can be considered as being made up of  
23 horizontal and vertical lines 16a, 16b defining a number of grid  
24 squares of side length 300 $\mu$ m, together with a number of  
25 intersections 16c where horizontal and vertical lines cross. One dot  
26 14 is provided at each intersection 16c, but offset slightly in one of  
27 four possible directions up, down, left or right, from the actual  
28 intersection 16c. The dot offsets are arranged to vary in a  
29 systematic way so that the pattern formed by any group of a  
30 sufficient number of dots, for example a group of 36 dots arranged in  
31 a six by six square, will be unique within a very large area of the

1 pattern. An example of this type of pattern is described in  
2 WO 01/26033.

3

4 Figure 2 schematically shows a digital pen 20 adapted to write  
5 human readable ink in non-machine-readable IR transparent ink and  
6 to read a position dot pattern in infra-red. The pen 20 has a housing  
7 22, a processor 24 with access to memory 26, a removable and  
8 replaceable ink nib and cartridge unit 28, a pressure sensor 29  
9 adapted to be able to identify when the nib is pressed against a  
10 document, an infra-red LED emitter 30 adapted to emit infra-red light  
11 of a specified wavelength, an infra-red sensitive camera 32 (e.g. a  
12 CCD or CMOS sensor), a wireless telecommunications transceiver  
13 34, and a removable and replaceable battery 36. Such a pen exists  
14 today and is available from Anoto as the Logitech IO™ pen.

15

16 The pen 20, when in use writing or marking the page 10, images a  
17 6x6 array of dots 14. The pen's processor 24 establishes its position  
18 in the dot pattern 12 from that image. The processor 24 processes  
19 data acquired by the camera 32 and the transceiver 34  
20 communicates processed information from the processor 24 to a  
21 remote complementary transceiver (e.g. to a receiver linked to a PC).  
22 Typically that information will include information related to where in  
23 the dot pattern the pen is, or has been, and its pattern of movement.

24

25 Anoto intend that their digital paper, offset-printed with dot pattern,  
26 either over the whole of its surface or over selected regions, be  
27 available from specially registered printing companies who know the  
28 technologies necessary to achieve good results. End users must buy  
29 their paper pre-printed with machine-readable position dot pattern  
30 and pre-printed with human readable content (e.g. text, or pictures,  
31 or lines, or boxes or frames etc).

1

2 This is to avoid problems. One problem avoided by such a system is  
3 that of users who design their own forms or documents, printing  
4 human-discriminable or readable content over the dot pattern with the  
5 wrong ink (ink that is IR-absorbing ink), thereby masking the dot  
6 pattern from the digital pen, when the pen is used.

7

8 Another problem avoided by such a system is that of the digital  
9 pattern 12 being printed with characteristics that are different to  
10 those required for it to be read by the pen 20. In the Anoto system,  
11 as in other digital paper systems, the relative positions and sizes of  
12 the elements of the pattern are controlled to be within pre-set  
13 tolerances. In this manner, a pattern may be printed which conforms  
14 to the specifications of the system and which is suitable for use with  
15 the pen. In the case of the Anoto system, for example, examples of  
16 elements of the pattern that are controlled to be within pre-set  
17 tolerances include: the spacing between adjacent parallel lines of the  
18 grid 16; the distance by which the dots 14 are offset from their  
19 corresponding grid intersections 16c; and, the diameter of the dots  
20 14. Many printers have technical characteristics which render them  
21 unable to reliably print the elements of such a pattern, such that the  
22 relative positions and the sizes of the pattern elements meet the pre-  
23 set tolerances. Many existing home and office printers, for example,  
24 are unable to reliably do so. For this reason, Anoto intend that the  
25 digital pattern 12 is printed using offset printers, which are able to  
26 print it with sufficient quality and with sufficient resolution in order  
27 that it may be read by the pen without error.

28

## 29 SUMMARY OF THE INVENTION

30 According to a first aspect of the invention, there is provided a printer  
31 system comprising a printer adapted to print a location pattern

1 comprising a plurality of dots, each having a substantially  
2 predetermined size and nominal position in the pattern, the printer  
3 having a resolution constraining the position at which the dots may  
4 be printed, the system being adapted to modify at least some of the  
5 dots prior to printing such that the modified dots have an optical  
6 centre of gravity that more closely coincides with their nominal  
7 positions.

8

9 The present invention also extends to: software and a printer driver  
10 for generating such a location pattern; and, corresponding methods  
11 for generating or printing such location patterns; as defined in the  
12 appended claims.

13

#### 14 BRIEF DESCRIPTION OF THE DRAWINGS

15 For a better understanding of the invention and to show how the  
16 same may be carried into effect, there will now be described by way  
17 of example only, specific embodiments, methods and processes  
18 according to the present invention with reference to the  
19 accompanying drawings in which:

20

21 Figure 1a shows schematically a sheet of Anoto digital paper;

22

23 Figure 1b shows schematically an enlarged portion of the sheet  
24 illustrated in Figure 1a;

25

26 Figure 2 shows schematically a known digital pen;

27

28 Figure 3 shows schematically a system for creating and printing a  
29 digital document according to one embodiment of the invention;

30

1 Figure 4a is a flow diagram showing a method of designing an  
2 electronic document according to an embodiment of the present  
3 invention;

4

5 Figure 4b is a flow diagram showing a method of generating a digital  
6 pattern and digital document according to an embodiment of the  
7 present invention;

8

9 Figures 5a and 5b schematically illustrate exemplary digital  
10 documents printed according to embodiments of the present  
11 invention;

12

13 Figure 6a is a schematic illustration of dots forming part of a digital  
14 pattern printed using a conventional laser printing process;

15

16 Figures 6b-e are schematic illustrations of dots forming part of a  
17 digital pattern printed using a printing process according to  
18 embodiments of the present invention; and,

19

20 Figures 7a and 7b show enlarged views of an individual dot shown in  
21 Figures 6b and 6c, respectively.

22

### 23 DETAILED DESCRIPTION OF THE INVENTION

24 There will now be described, by way of example only, the best mode  
25 contemplated by the inventors for carrying out embodiments of the  
26 invention.

27

28 Figure 3 is a schematic illustration of a system 50 for printing a  
29 document having a pattern, according to an embodiment of the  
30 invention.

31

1 The system 50 comprises a workstation 51 including a personal  
2 computer (PC) 52 which is connected to a local printer 60. In  
3 practice, the printer may instead be connected to the PC 52 via a  
4 network. The PC 52 may also be connected to the Internet 62. The  
5 PC 52 includes a user interface including a screen 58, a keyboard 54  
6 and a mouse 56. The PC 52 has as a processor 52a, a memory 52b,  
7 and I/O software devices 52c by means of which the processor  
8 communicates with the screen 58, the keyboard 54 and the mouse  
9 56 and a communications port 57 by means of which it  
10 communicates with the Internet 62 or a local network such as a  
11 LAN 59 having peripheral devices and/or other computers (e.g. PCs)  
12 59a.

13

14 The workstation 51 has access to a database 52d of pattern data for  
15 use with Anoto-type digital documents. The database 52d may also  
16 have user names and identification numbers, which are in use  
17 associated with each particular document at the time of printing of  
18 the document and which may be printed out with the document. This  
19 database 52d may be on the PC or elsewhere on a network, for  
20 example on a local file server or on the Internet. This may take the  
21 form of a digital pattern space allocation server as is used in the  
22 Anoto system. The PC 52 also includes a software tool, known as a  
23 Print-on-Demand (PoD) tool, referenced 52e the figure. The PoD  
24 tool 52e has access to the database 52d of pattern data, as is  
25 described in more detail below.

26

27 The PC 52 is arranged to generate electronic digital documents that  
28 comprise a pattern 12 of dots 14. The digital documents may be  
29 "Anoto-type" digital documents. However, it will be appreciated that  
30 the invention is not restricted to use with any proprietary system.

31

1 In certain embodiments of the invention, the digital documents may  
2 be printed such that they have both a pattern 12 of dots 14 and  
3 human-discriminable content. The human-discriminable content may  
4 include amongst other things include text, graphics and check boxes,  
5 for example. Figure 5a illustrates schematically a hard (paper) copy  
6 of such a digital document. The hard copy comprises a carrier 70a in  
7 the form of a single sheet of A4 paper, with the machine-readable  
8 pattern 12 of dots 14 printed on it. In this example, the user has  
9 defined the pattern area to cover the entire area of the carrier 70a,  
10 as can be seen from the figure. Also printed on the paper 70a are  
11 further markings 72a-c, which are clearly visible to a human user of  
12 the form, and which make up the human-discriminable content of the  
13 document. In the example illustrated the content is made up of a  
14 schematic image of a flower 72a, the word "SEND" 72b and a check  
15 box 72c. The nature and amount of the content will depend entirely  
16 on the intended use of the document.

17

18 Such digital documents may be used for specific functions, such as  
19 questionnaires or forms, for example. Suitable techniques for  
20 simultaneously printing a digital pattern and human-discriminable  
21 content on printers, such as inkjet and laser printers, are more fully  
22 described in the co-pending British patent application, incorporated  
23 by referenced above, entitled "Methods, apparatus and software for  
24 printing location pattern", (Hewlett-Packard reference 200300566-1;  
25 Attorney docket JL3824).

26

27 In certain methods of the invention, the digital documents are printed  
28 with no, or substantially no human-discriminable content. Thus, the  
29 resultant printed digital documents in such methods are suitable for a  
30 wide variety of uses by a user; i.e. they may be used as the digital  
31 equivalent of blank notepaper. Figure 5b illustrates schematically a

1 hard (paper) copy of such a digital document. The hard copy again  
2 comprises a carrier 70b in the form of a single sheet of A4 paper,  
3 with the machine-readable pattern 12 of dots 14 printed on it. In this  
4 example, the user has defined the pattern area to cover the entire  
5 area of the carrier 70b, as can be seen from the figure. As can be  
6 seen from the figure, there are no markings printed on the paper 70b,  
7 for human use.

8

9 The user interface of the PC 52 allows a user to the view electronic  
10 versions of digital documents to be printed, using a conventional  
11 software viewer application, referenced 52f in Figure 3, on the screen  
12 58. An already existing, previously designed document may be  
13 accessed from a database of such documents for printing.  
14 Alternatively, a new document may be designed by the user. The  
15 user may make modifications to the digital documents prior to  
16 printing them should this be required. Such changes may include  
17 modifying any human-discriminable content that may be present in the  
18 document or modifying the area or areas, in terms of size or shape  
19 for example, on the digital document that are to have digital pattern  
20 applied to them. This may be achieved through the user interface,  
21 which includes the keyboard 54 and mouse 56 and software (not  
22 shown) for processing inputs from them, as well as the screen 58  
23 and software 52g for producing the content, e.g. images and/or text,  
24 on the screen.

25

26 Techniques for allowing a user to modify and print, on demand,  
27 documents which have position identifying pattern on them for use  
28 with a digital pen and paper system are more fully described co-  
29 pending British patent application, incorporated by referenced above,  
30 entitled "Printing of documents with position identification pattern",

1 (Hewlett-Packard reference 200310132-1; Attorney docket  
2 ASW1329).

3

4 Figure 4a is a flow diagram showing an exemplary method of  
5 designing a generic electronic digital document suitable for use with  
6 embodiments of the present invention. The method starts at step 2  
7 with the design of the human-discriminable content of the document.  
8 The design work is carried out on the PC using a software  
9 application. The application may, for example, be Acrobat Reader or  
10 a word processing package such as 'Word', a database package  
11 such as 'Access', or a spreadsheet package such as 'Excel'. Each of  
12 these applications may be used to design the content of the  
13 document. The content is converted to PDF format at step 4. It will  
14 be understood that in the event that no human-discriminable content is  
15 incorporated into the documents, the steps 2 and 4 may be omitted  
16 from the method.

17

18 The machine-readable pattern areas of the document are then  
19 defined at step 6. In this case this is carried out using a form design  
20 tool (FDT) 52h, shown in Figure 3, which in the present embodiment  
21 is in the form of an Acrobat 5.0 plug-in. In one simple case, the  
22 machine-readable pattern area of the document may be the entire  
23 page; which may be a single A4 sheet for example. This may even  
24 be set as the default setting at this step.

25

26 At step 8 the user allocates any desired computer-implemented  
27 functions to one or more areas of pattern in the document. In this  
28 manner, such a pattern area may code for instructions to perform the  
29 associated function. For example, a "send" function may be  
30 designated by a user to the pattern area associated with the box 72c  
31 of the document 70a shown in Figure 5a, for example. In this way,

1 when the pen is used to check the box 72c, the system knows that  
2 the updating of the document 70a is complete. In one simple case,  
3 such a document need have no such computer-implemented  
4 functions.

5

6 At step 10 a name is given to the document.

7

8 Once the user is happy with the design of the digital document, it  
9 may be printed out.

10

11 The process of printing a document according to the present  
12 embodiment, including the generation of a modified position  
13 identifying pattern will now be described with reference to the flow  
14 diagram in Figure 4b. In this example, a digital document consisting  
15 of single sheet of A4 is printed. For the purposes of clarity, this  
16 exemplary document has no human-discernable content and has a  
17 machine-readable pattern of dots printed over its entire surface, such  
18 as is illustrated in Figure 5b.

19

20 At step 2, the user initiates the printing process, by selecting a  
21 printing option on a user interface (UI) (not shown). This causes the  
22 PoD tool, referenced as 52e in Figure 3, to open a printing UI in a  
23 conventional manner. Using the printing UI the user requests the  
24 number of prints and various other printing parameters (e.g. whether  
25 the printed document is to be in colour or black and white, etc.). At  
26 step 4, the PoD tool 52e identifies from the document file name that  
27 the document is a document having a position identifying pattern on  
28 it. The PoD tool 52e then identifies those printers on the network  
29 which the user may select to print the print job, at step 6. In the  
30 present example, this includes the printer 60. The user selects the

1 printer 60 and initiates the print operation, in a conventional manner,  
2 at step 8.

3

4 In the present embodiment, the printer 60 is a conventional laser  
5 printer with a resolution of 600dpi, such as is conventionally used in  
6 office environments. However, in other embodiments of the invention  
7 other types of printer may be used. These may include inkjet  
8 printers, LED printers, LCD printers, Liquid Electrophotographic  
9 Printers. Photocopiers can also be considered as printers. The  
10 difference between an electrostatic, toner-based, photocopier and a  
11 laser printer is not significant for many aspects of the invention.  
12 Indeed, it is not uncommon for computers, e.g. PCs to be configured  
13 to print from photocopiers.

14

15 Once the actual print is initiated, the PoD tool 52f allocates a unique  
16 instance ID to the printed document, at step 10. It then requests the  
17 required amount of pattern space from the database 52d of pattern  
18 data, at step 12, providing the document name and instance ID. In  
19 the current example, the requested pattern area is sufficient to cover  
20 substantially all of the document, in this example a sheet of A4  
21 paper, as stated above. For other examples, only some areas of the  
22 document will need to be allocated a digital pattern.

23

24 An area of pattern is allocated at step 14 to the document from a  
25 virtual pattern space stored in the database 52d. In the present  
26 example, the PoD tool 52e receives back from the database 52d a  
27 definition of the pattern space allocated. In the present embodiment,  
28 this is in the form of a co-ordinate reference within the total pattern  
29 space. This may take the form of, for example, upper left and lower  
30 right co-ordinates of the allocated area in the pattern space. The  
31 workstation 51 is then able to re-create the dot pattern in the

1 allocated area from that information in a conventional manner. In  
2 other embodiments, a full definition of the actual pattern to be used  
3 may be transmitted from the database 52d to the PoD tool 52e. Such  
4 a full definition may take the form of co-ordinate positions, for  
5 example, of each dot in the allocated area.

6

7 At this stage, it will be appreciated that the definition of the dot  
8 pattern contains the nominal, or ideal positions of the dots which lie  
9 in the allocated pattern space. Furthermore, the size and form of the  
10 individual dots in the allocated pattern space are defined only by the  
11 specification of the system. In the case of the Anoto system, for  
12 example, the dots are circular with a diameter of approximately  
13 100 $\mu$ m.

14

15 The PoD tool 52e then obtains, at step 16, data relating to the  
16 printing characteristics of the selected printer; printer 60. In the  
17 present embodiment, this information is stored locally with respect to  
18 the workstation 51, in the memory 52b of the PC 52. In other  
19 embodiments, however, this information may be stored on a server  
20 connected to a network such as a LAN or the Internet 62. The  
21 printing characteristics data informs the PoD tool 52e that the printer  
22 60 should print a digital pattern with modified dots, or with a modified  
23 dot shape, in order that the printed pattern may be more reliably read  
24 by the pen 20. The printing characteristics data also defines the  
25 modified dot shape for use with the digital pattern. Furthermore, the  
26 printing characteristics data also defines the position(s) and  
27 orientation(s) of the modified dot shape with respect to one or more  
28 exemplary virtual grid intersection 16c. This information may be  
29 used, when generating the digital pattern, to ensure that each of the  
30 modified dots in the pattern is correctly positioned and orientated  
31 with respect to its corresponding virtual intersection 16c. In this

1 manner, it may be ensured that the pattern may be reliably read by  
2 the pen. This definition, in the present embodiment, is given in the  
3 native resolution of the printer 60 and is employed when printing the  
4 document with the printer 60.

5

6 Referring now to Figure 6 various exemplary parts of digital dot  
7 patterns are illustrated. In Figure 6a, four dots 80a-d forming an  
8 exemplary part of a digital pattern, printed in a conventional manner  
9 with a digital printer of 600dpi resolution, are illustrated. In the  
10 figure, the position of the intersections of the imaginary gridlines are  
11 indicated by crosses 82. As can be seen from the figure, the dots  
12 80a-d are located, respectively above, to the right, below and to the  
13 left of their adjacent or corresponding crosses 82. The figure is  
14 shown, for ease of explanation, against an imaginary background  
15 grid. Each of the individual squares making up the grid represent the  
16 smallest individual unit of addressable printable area; i.e. the  
17 smallest individual unit of area which may be printed by the printer  
18 60. Thus, the grid represents the native resolution of the printer.  
19 Thus, each of the pixels which may be printed by the printer 60  
20 substantially fills a given square. It will thus be understood that  
21 since the native resolution of the printer 60 is 600dpi, the length of  
22 each of the individual squares making up the grid is 42.3 $\mu$ m.  
23 Similarly, the diameter of each pixel it prints is approximately 42 $\mu$ m.  
24 It can thus be seen that crosses 82 are separated by their immediate  
25 neighbours in the horizontal and vertical directions by 7 individual  
26 squares. This equates to 296.3 $\mu$ m, which is approximately equal to  
27 the 300 $\mu$ m as used in the Anoto system.

28

29 In this example, using conventional digital printing techniques, the  
30 circular dot shape is approximated by a 2 by 2 pixel array, as can be  
31 seen in the case of each of the dots 80a-d. Thus, the minimum

1 diameter of each of the dots 80a-d is approximately  $2 \times 42\mu\text{m}$ , which  
2 gives a diameter of approximately  $84\mu\text{m}$ .

3

4 It has been found by the inventors in experimentation with a range of  
5 laser printers that in the absence of other errors, printed digital  
6 patterns having a separation distance between adjacent parallel lines  
7 of the grid 16 (i.e. the distance separating the crosses 82 from their  
8 immediate neighbours in the horizontal and vertical directions) of  
9  $296.3\mu\text{m}$ , may be read by the pen 20 in a reliable manner.  
10 Furthermore, it has also been found by the inventors in  
11 experimentation with a range of laser printers that in the absence of  
12 other errors, printed digital patterns, having dots with a minimum  
13 diameter of approximately  $84\mu\text{m}$ , such as dots 80a-d, may be read by  
14 the pen 20 in a reliable manner.

15

16 It will be recalled that "dot offset distance" is the distance separating  
17 the optical centre of gravity of a given dot from the its adjacent  
18 gridline intersection point. It will be understood that the optical  
19 centre of gravity of a  $2 \times 2$  pixel array, such as any one of dots 80a-d,  
20 lies at the centre of the  $2 \times 2$  pixel array. Thus, the "dot offset  
21 distance" for dot 80a, for example, is referenced "d" in the figure. As  
22 can be seen from the figure, the "dot offset distance" is equal to the  
23 width of one individual squares making up the grid; i.e.  $42.3\mu\text{m}$ .

24

25 It has been found in experimentation by the inventors that digital  
26 patterns, printed with a range of laser printers, which have a "dot  
27 offset distances" equal to  $42.3\mu\text{m}$ , such as that of Figure 6a, may not  
28 be read by the pen 20 in a reliable manner. It has been found that  
29 this "dot offset distance" is too small to comply with the pre-set  
30 tolerances of the system. Consequently, digital pattern which is  
31 printed with such a "dot offset distance" does not conform to the

1 specifications of the system. Thus, due to the resolution limitations  
2 of the printers, a digital dot pattern may not be reliably read by a pen  
3 20, when it is printed by such printers, using conventional  
4 techniques.

5

6 Furthermore, it has been found by the inventors that if the "dot offset  
7 distance" is increased, the resultant pattern still may not be reliably  
8 read by a pen 20. Due to the resolution constraints of such printers,  
9 printed pattern with increased "dot offset distance" also does not  
10 conform to the specifications of the system; this time because the  
11 increased "dot offset distance" is too large. Alternatively, other  
12 aspects of the pattern are found to be forced outside the range of  
13 pre-set tolerances of the system. Thus, the result is similar; namely,  
14 that the resultant printed pattern does not conform to the  
15 specifications of the system, and is not reliably read by the pen 20.

16

17 Referring now to Figures 6b-6e, exemplary sets of dots, each forming  
18 part of a digital pattern with a modified dot shape according to  
19 embodiments of the present invention, are illustrated. In each of the  
20 Figures 6b-6e, four dots are illustrated adjacent the intersection  
21 points of imaginary gridlines. These intersection points are again  
22 indicated by crosses, as was the case in Figure 6a. In each of the  
23 figures, each dot occupies a different position (i.e. above, to the  
24 right, to the below and to the left) relative to its corresponding cross,  
25 as was the case in Figure 6a. Additionally, as was also the case in  
26 Figure 6a, each of the Figures 6b-6e is shown, for ease of  
27 explanation, against a background grid, where each individual square  
28 of the background grid represents the smallest individual unit of area  
29 which may be printed by the printer 60. The length of the sides of  
30 each of the individual squares of the grids shown in Figures 6b-6e is  
31 again 42.3 $\mu$ m.

1

2 It will be understood by the skilled reader that the representations of  
3 dot patterns illustrated in Figures 6b-e are schematic, or idealised  
4 illustrations. These schematic illustrations may most closely  
5 resemble a raster image or bit map of the dots prior to being printed.  
6 This may be as generated in application software, such as the PoD  
7 tool 52e, or as in the data processed by the printer driver (referenced  
8 52i in Figure 3), prior to being sent to the printer 60. It will of course  
9 be appreciated that when the dots are in fact printed, the printed  
10 shape of a dot may vary somewhat from the schematic shapes  
11 illustrated. This may be due to several factors. One of these is due  
12 to imperfections of the print engine, which causes its printed output  
13 to be only an approximation of the pre-printed image.

14

15 Referring now to Figure 6b, it can be seen that the dot 84c is made  
16 up of four pixels, in the form of a capital "T". The remaining dots  
17 84a, 84b and 84d have the same size and shape as the dot 84c (i.e.  
18 have the same number and configuration of pixels) but are each but  
19 are located at a different orientation relative to their adjacent crosses  
20 82. It will in fact be clear to the skilled reader that rotating the dot  
21 84c, +90, 180 and +270 degrees about its adjacent cross yields the  
22 orientational and positional relationship of dots 84d, 84a and 84b,  
23 respectively, relative to their respective adjacent crosses.

24

25 Referring now to Figure 7a, an enlarged view of the dot 84a, is  
26 shown. The individual pixels forming the dot are referenced W, X, Y  
27 and Z. It may be immediately seen from this figure that the optical  
28 centre of gravity of the group of pixels X, Y and Z lies at the  
29 intersection of the line Y-Y, which passes through the corresponding  
30 cross 82, and line X<sub>3</sub>-X<sub>3</sub>, lying perpendicular to line Y-Y. Similarly, it  
31 may be seen that the optical centre of gravity of the pixel W lies at

1 the intersection of the lines Y-Y and X<sub>1</sub>-X<sub>1</sub>. Simple ratios show that  
2 the optical centre of gravity of the whole dot, including pixels W, X, Y  
3 and Z lies on the intersection between the lines Y-Y and X<sub>2</sub>-X<sub>2</sub>, which  
4 lies parallel to and between the lines X<sub>1</sub>-X<sub>1</sub> and X<sub>2</sub>-X<sub>2</sub>; where, the  
5 distance separating the lines X<sub>2</sub>-X<sub>2</sub> and X<sub>3</sub>-X<sub>3</sub> is one third that  
6 separating the lines X<sub>2</sub>-X<sub>2</sub> and X<sub>1</sub>-X<sub>1</sub>.

7

8 The optical centre of gravity of the dot 84a is therefore indicated at  
9 point "C". Its distance from the centre of the cross 82 is given by the  
10 distance "d", which is equal to 1.25 of the length of an individual  
11 square of the grid shown in Figures 6b-6d; i.e. 1.25 x 42.3 $\mu$ m, which  
12 equals 52.9 $\mu$ m. This distance is of course the "dot offset distance".  
13 It will be understood that the same value for the "dot offset distance"  
14 is obtained in the case of each of the remaining dots 84b, 84c and  
15 84d. It has been found that the modified dot pattern indicated in  
16 Figure 6b with the "dot offset distance" of 52.9 $\mu$ m results in printed  
17 pattern that may be reliably read by the pen 20. Thus, it will be  
18 understood that using the modified dot shape of Figure 6b, the "dot  
19 offset distance" may be brought within the tolerances of the system.  
20 In this manner, a printed digital pattern that conforms to the  
21 specifications of the system may be printed with a printer such as  
22 printer 60.

23

24 Figure 6c, shows an alternative dot pattern. In this dot pattern, dots  
25 86a-d of the same shape and size as described with reference to  
26 Figure 6b are employed.

27

28 In this case, rotating the dot 86a 180 degrees about its adjacent  
29 cross yields the orientational and positional relationship of dot 86b  
30 relative to its adjacent cross. The pair of dots 86c and 86d have a  
31 similar rotative relationship relative to their adjacent crosses.

1 However, it will be noted that this is not the case between other  
2 pairings of these four dots, which have reflective or a combination of  
3 rotative and reflective relationships regarding their orientation and  
4 position relative to their adjacent crosses.

5

6 As can be seen from the figure, the positions and orientations of a  
7 given dot in the pattern shown in Figure 6c differs from the  
8 corresponding dot shown in the Figure 6b. Taking for example the  
9 dot 86c, which is located offset below its cross. This dot is inverted  
10 relative to the corresponding dot, dot 84c, of figure 6b which is  
11 located offset below its cross. Alternatively, this may be view as the  
12 stem of the "T" of dots 86a and 86c are directed towards their  
13 respective, adjacent crosses, whereas the opposite is true in the  
14 case of the dots 84a and 84c. Furthermore, whereas the dot 84c is  
15 located so as to be symmetrical about the line Y-Y (shown in Figure  
16 7a) which passes through its adjacent cross, the dot 86c is offset not  
17 only below its adjacent cross, but also somewhat to the left, as  
18 viewed in the image.

19

20 An enlarged view of the dot 86a, is shown in Figure 7b. This is  
21 illustrated in the same manner that the dot 84a was illustrated in  
22 Figure 7a. The optical centre of gravity of the dot 86a is illustrated  
23 by the cross referenced "C<sub>1</sub>". This may be determined in the same  
24 manner as was used with reference to Figure 7a. As can be seen  
25 from Figure 7b, optical centre of gravity of the dot 86a is again  
26 located 1.25 of the length of an individual square of the grid shown in  
27 Figures 6b-6d from the cross 82 in the direction Y-Y; i.e. 52.9 $\mu$ m.  
28 Again as stated above, it has been found that "dot offset distance" of  
29 52.9 $\mu$ m results in printed pattern that may be reliably read by the pen  
30 20 when printed with a printer such as printer 60.

31

1 It will be noted, however, that the optical centre of gravity of the dot  
2 86a is also located a distance "d<sub>x</sub>" offset in a direction perpendicular  
3 to the direction Y-Y; to the left of its cross, as viewed in the figure.  
4 The distance "d<sub>x</sub>" in this case is half of the length of an individual  
5 square of the grid shown in Figures 6b-6d; i.e. 21.2 $\mu$ m. In practice  
6 however, this offset distance "d<sub>x</sub>", in a secondary direction, has been  
7 found to be acceptable for use with the Anoto system in the case of  
8 this dot pattern.

9

10 Figure 6d, shows a further alternative dot pattern. In this dot pattern,  
11 dots 88a-d consisting of three pixels arranged in an "L" shape are  
12 used. The dots in this dots pattern have the same rotative, positional  
13 and orientational relationship relative to their adjacent crosses as do  
14 the dots in the pattern shown in Figure 6b. Like the dot pattern of  
15 Figure 6c, however, the optical centre of gravity of each of the dots  
16 88a-d is offset from its corresponding cross, in both a primary  
17 direction and a secondary direction. Like the pattern of Figure 6c,  
18 though, the dot pattern of Figure 6d has been found to work well with  
19 the pen 20 when printed using a 600dpi laser printer.

20

21 Figure 6e, shows a further alternative dot pattern. This dot pattern  
22 resembles the dot pattern shown in Figure 6d in that dots 90a-d  
23 consisting of three pixels arranged in an "L" shape are used. Like  
24 the dot patterns of shown in Figures 6c and 6d, the optical centre of  
25 gravity of each of the dots 90a-d is offset from its adjacent cross, in  
26 both a primary direction and a secondary direction. Additionally,  
27 however, the dots 90a-d have similar orientational and positional  
28 relationships, relative to their adjacent crosses, as is the case with  
29 the dots making up the dot pattern illustrated in Figure 6c. Again,  
30 the dot pattern of Figure 6e has been found to work well with the pen  
31 20 when printed using a 600dpi laser printer.

1

2 It has been found that for printers which benefit from the use of a  
3 digital pattern with a modified dot shape, the exact characteristics of  
4 the dots (including their shape size and orientations) which is most  
5 beneficial vary with the individual printer concerned. Thus, for a  
6 given printer the dot characteristics that are used may be determined  
7 by experimentation. Furthermore, it will be understood that the  
8 example dot types given in figures 6b-e have been found to work well  
9 with various widely used types of home and office printers. However,  
10 the use of dots, with a differently modified combination of shape, size  
11 and orientation may be preferable for use with other printers. Such  
12 dot may, for example, use: a different number of pixels per dot to  
13 those shown in figures 6b-e; one or more differently shaped dots;  
14 dots of a shape different to those given in figures 6b-e; or, different  
15 aspects of the patterns given in figures 6b-e.

16

17 Returning now to the Figure 4b, it will thus be understood that any  
18 one of the patterns of modified dots illustrated in Figures 6b-e, or  
19 indeed a further pattern of modified dots may be specified in the  
20 printing characteristics of the printer 60 obtained at step 16 of Figure  
21 4b.

22

23 At step 18 of Figure 4b, the PoD tool 52e in conjunction with the  
24 workstation 51 re-creates the dot pattern which is to be printed, using  
25 the modified dot shape pattern, obtained at step 16, and converts  
26 this into a print file ready for printing in a conventional manner. In  
27 the present embodiment, the dot pattern which is to be printed is re-  
28 created as a bit map, although any other suitable format may instead  
29 be used.

30

1 At step 20, the print file is then converted into a language that can be  
2 understood by the printer driver 52i (illustrated in Figure 3)  
3 associated with the workstation 51 and is sent to the printer driver  
4 52i. Examples of a suitable language are PCL5 or Postscript.  
5 However, other languages may instead be used.

6

7 At step 22, the print file is sent to the printer 60, where the document  
8 is printed.

9

10 In the present example, the printer 60 may be a monochrome printer,  
11 which typically prints in black ink. Alternatively, it may be a colour  
12 printer, typically printing in black and three complementary colour  
13 inks. In either case, the digital pattern is printed in the present  
14 embodiment using an ink that absorbs light at a non-visible  
15 wavelength of light, such that the dots may be read by the pen 20. It  
16 will be understood that the term "ink" is meant to include liquid inks,  
17 and powder inks (e.g. toner that needs heat to fuse to a  
18 page/surface) and gels: it is not used in a sense to restrict its  
19 physical form.

20

21 As is well understood in the art, human-discernable content normally  
22 undergoes a half-toning and masking operation prior to printing in  
23 order to determine what content, if any, is printed at each pixel of the  
24 printing operation. However, it will be understood that the digital  
25 pattern may bypass a half-toning operation. In the present  
26 embodiment, the pixels of the digital pattern may either be "on" or  
27 "off", with no shades of intensity between those extremes. The  
28 digital pattern data may be sent from a colour separation stage  
29 directly to a masking stage, or even directly to the printer.

30

1 It will also be appreciated that where the digital document is to be  
2 printed on the same carrier as human-discernible content, it may be  
3 desirable to use inks with different characteristics. For example, the  
4 digital pattern may be printed using an ink that absorbs IR radiation  
5 and the human-discernible content may be printed using human  
6 readable, IR transparent ink. In this manner, the risk of the human-  
7 discernable content obscuring or masking the digital pattern may be  
8 avoided.

9

10 In one such embodiment of the invention, a four-colour laser or inkjet  
11 printer may be used. The digital pattern is printed using an infra-red  
12 absorbing black ink. The human-discernable content is printed using  
13 cyan, magenta and yellow inks that are not infra-red absorbing. In  
14 this embodiment, the black ink channel is processed separately from  
15 the cyan, magenta and yellow channels. In this manner, the human-  
16 discernable content and the digital pattern may be maintained  
17 separate. This and other methods of simultaneously printing human-  
18 discernable content and the digital pattern with laser and other types  
19 of printers are more fully described co-pending British patent  
20 application, incorporated by referenced above, entitled "Methods,  
21 apparatus and software for printing location pattern", (Hewlett-  
22 Packard reference 200300566-1; Attorney docket JL3824).

23

24 It will thus be understood that embodiments of the present invention  
25 may be used to permit printers which may otherwise not be able to  
26 print a digital pattern sufficiently accurately to be correctly read, by  
27 employing dots of a shape which modifies the optical centre of  
28 gravity of each dot. In this way, an apparent lack of printer  
29 resolution may be compensated for. It will be understood that  
30 embodiments of the present invention may be particularly useful in

1 allowing existing printers to be successfully used with such digital  
2 pattern systems.

3

4 **FURTHER EMBODIMENTS**

5 In the above description numerous specific details are set forth in  
6 order to provide a thorough understanding of the present invention.  
7 It will be apparent however, to one skilled in the art, that the present  
8 invention may be practiced without limitation to these specific details.  
9 In other instances, well known methods and structures have not been  
10 described in detail so as not to unnecessarily obscure the present  
11 invention.

12

13 For example, although in the above-described embodiment, the  
14 characteristics of the modified dots were defined in a bit map, the  
15 skilled reader will appreciate that in other embodiments of the  
16 invention, this need not be the case. The dots or other position  
17 determining markings according embodiments of the present  
18 invention may be defined using any suitable method that explicitly  
19 defines, in the printer's native resolution, the pixels which are to be  
20 used in order to print the dots or the position determining markings.  
21 For example, this may be achieved using a font set or a high level  
22 programming language.

23

24 For example, the skilled reader will appreciate that in some  
25 embodiments of the invention, the variable which is used to modify  
26 the characteristics of the dots that make up the digital pattern need  
27 not be, or need not be only the resolution of the printer. Other  
28 factors which affect the optical appearance of such dots, and the way  
29 in which they are read by a reader such as the pen 20, may include  
30 the media type being used. For example, whether the media is  
31 glossy or matt, recycled or not recycled, or indeed whether the media

1 is made from non-paper based material, such as acetate.  
2 Additionally, the ink characteristics of the printer being used may  
3 also affect the appearance of the digital pattern, and the way in  
4 which they are read by a reader such as the pen 20. For example, in  
5 the case of a laser printer, different levels of toner density will  
6 change the appearance of the dots of the dot pattern. Alternatively,  
7 the colour with which the dots are printed will also change their  
8 appearance. It will be understood that different levels of grey, in the  
9 case of a black, monochrome pattern will have this effect.  
10 Additionally, a change in the hue of the colour will likewise have such  
11 an effect. For example, such a pattern may be more visually  
12 pleasing, or indeed may be more easily read by a pen, depending  
13 upon the colour and material of the carrier, if it is printed in any one  
14 of a range of non-grey colours, such as blue, yellow or red.

15

16 It will thus be understood that, for any given digital paper system,  
17 operating under given conditions (which may include paper type, ink  
18 characteristics, printer resolution etc), a digital pattern with preferred  
19 modified dot characteristics (including one or more of shape, size  
20 and orientation) may be determined using conventional experimental  
21 techniques. A number of such operating conditions may be stored in  
22 a look up table in the memory of a workstation, such as workstation  
23 51 for example, together with their corresponding preferred modified  
24 dot characteristics. When the user prints a digital document in such  
25 an embodiment, he may select via a conventional UI the operating  
26 conditions that match, or most closely match the current operating  
27 conditions of his system. In this manner, he may reduce the  
28 likelihood that the subsequently printed digital pattern will not be  
29 correctly readable.

30

- 1    It will of course be understood that other position identifying patterns
- 2    may equally be used in conjunction with embodiments of the present
- 3    invention. Some examples of other suitable patterns are described in
- 4    WO 00/73983 and WO 01/71643.